THE ROLE OF PERIPHERAL VISION AND VISUAL VESTIBULAR INTERACTIONS IN THE EXOCENTRIC PERCEPTION OF LINEAR MOVEMENT IN HUMANS.

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Presented by Alfred Fessard

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16. Abstract

The presentation, at the periphery of the visual field, of a scene animated by linear movement, induces a sense of linear displacement of the body in a direction opposite to that of the moving scene. The latencies, thresholds, and saturation limits of this phenomenon are described quantitatively, as well as the dynamic relations between the change of speed of the visual scene and the speed of the subject's displacement. Some modifications of the vestibular evaluation of linear movement were observed.

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THE ROLE OF PERIPHERAL VISION AND VISUAL VESTIBULAR INTERACTIONS IN THE EXOCENTRIC PERCEPTION OF LINEAR MOVEMENT IN HUMANS.

A Report (*) by Alain Berthoz, Bernard Pavard and Lawrence Young, presented by Alfred Fessard.

The presentation, at the periphery of the visual field, of a scene animated by linear movement, induces a sense of linear displacement of the body in a direction opposite to that of the moving scene. The latencies, thresholds, and saturation limits of this phenomenon are described quantitatively, as well as the dynamic relations between the change of speed of the visual scene and the speed of the subject's displacement. Some modifications of the vestibular evaluation of linear movement were observed. /1605*

It is known from the experiments of Mach [1] that a moving visual scene can induce in a subject, not only the sensation of displacement of the surrounding space (egocentric movement), but also, that of movement of the subject's own body (exocentric movement). This important contribution of the visual system to the perception of movement of the body, even though it often gives rise to illusions, has been the subject of only scattered studies [2, 3, 4]. However, it has recently been shown that the presentation of images that rotate about a horizontal or vertical axis induces respectively a modification of the subjective vertical and a sensation of exocentric movement [6, 7, 8]. This sensation conflicts with information of labyrinthine origin [5, 7] and involves a modification of vestibular thresholds [9]. /1606

We present here preliminary results that establish the role of peripheral vision in evaluating linear speed and the

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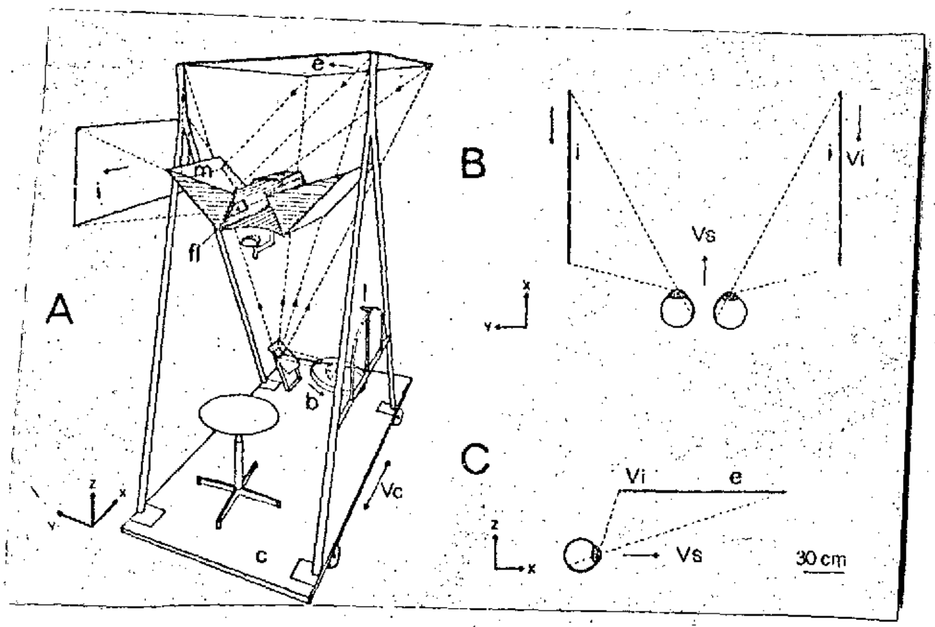

Fig. .--A. Experimental setup: the subject is seated on a cart (c). A projector rotates a transparent band (b) on which are drawn various signs (letters, points, crosses, etc.). The image of this band is projected on a screen (e) (area: 1.6 m^2, distance from the horizontal plane of the eyes: 0.5 m). The subject, whose head is positioned by a chin rest, sees through two lateral windows (fl) and one overhead opening cut in a black box. The virtual images (i) of the screen (e) are given by two mirrors (m) at 45° angles. A lever (l) at the right of the seat allows the subject to give a subjective evaluation of his or her speed Vs when the film is moving at the speed Vi or when the cart moves.

B. View from above which indicates the position of the images (i) relative to the eyes of the subject (angle of vision: approx. 20 to 70°). Vi is the speed of the images relative to the cart. Vs is the subjective speed of the subject.

C. View from the right, indicating the position of the screen (e). Note that Vs is slightly inclined downward.

interaction of this evaluation with information of non-visual origin concerning the translation of the body.

METHODS.--The subject is seated on a moveable cart (fig. 1), the displacement of which can be measured. Figures projected on the screen (e) move toward the front or toward the back, at speeds (Vi) varying between 0 and 2 m/sec. These variations in speed impulses are stepwise or sudden. A computer controls the speed of passage of the images Vi, and records the responses of the subject. In the case of a displacement of the cart, it also calculates the speed, the acceleration, and their correlations with the evaluation of Vs. Several series of experiments were performed, in the course of which the subject was instructed to look steadily at a point on the screen (e) (fixation point), or, having covered the overhead window, to fixate on a stationary horizontal line at the bottom of the black box. A standard procedure allows the subjective response of the subject to be calibrated at the beginning of each experiment.

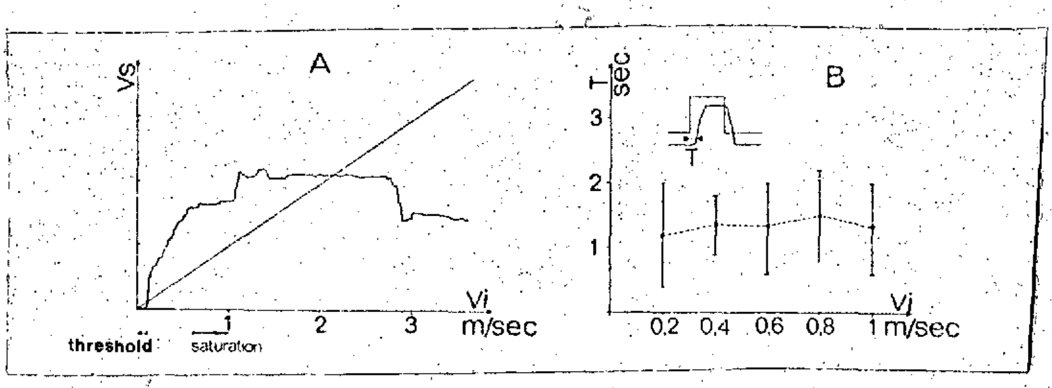

Fig. 2.--Dynamic characteristics of the subjective sensation of forward linear speed induced by the backward passage of images at the periphery of the visual field.

A. Variations in the subjective speed (Vs, arbitrary units) as a function of the speed of the images Vi.

B. Time of effect (T) of the sensation of subjective speed Vs for various stepwise changed in image cart-type speed Vi. Mean (.) and standard deviation for 10 subjects.

RESULTS.--The case when only the visual scene moves.--The movement of the images backward or forward created, in 29 subjects out of 30, the illusion of displacement with a sense opposite to that of the images. The strongest sensation is obtained with irregular figures arranged in a random fashion, and the sensation last for as long as the stimulus is presented. It is the whole consisting of the black box, the cart, and the subject's body that is perceived as moving rectilinearly with a speed Vs. When the instructions are to keep the gaze on the fixation point, this point seems to move relative to the surrounding space in the same direction as Vs. Viewing either the screen (e) or the images (i) separately is sufficient to produce the illusion, but the combined viewing of the two adds considerably to the impression of recti- /1607 linear movement, to which is added a constant sensation of inclination with respect to the horizontal. The direction of this inclination is always downward when Vs is forward, and upward when Vs is backward.

THRESHOLDS.--The threhold of speed of passage of the images, measured by the presenting of the step increase of Vi for which the sensation of movement appears, is very low in the subjects tested. it is often less than 1 cm/sec (mean: 1 cm/s, standard deviation: 0.5 cm/sec, for 20 subjects). In certain subjects the threshold is higher for Vs toward the front than towards the back. The relative threshold of the detection of a change in Vs, when Vi goes from a non-zero value to a greater or lesser value, is close to the absolute threshold. Beyond this, wehn Vi is increased past the threshold, Vs reaches a value at which there is a saturation of the effect (fig. 2A). This saturation occurs at about 0.8 m/sec under the conditions of our experiments (mean: 0.8 m/sec, standard deviation for 10 subjects: 0.4 m/sec). When Vi exceeds 1.5 m/sec, a relative decrease of Vs is sometimes observed.

TIME OF EFFECT.--The time of effect (T) is measured by calculating the time between the beginning of a step of Vi and the moment when the response Vs of the subject reaches 10% of its final value, which clearly indicates the perception of the sensation of movement (fig. 2B). Measurements on 10 subjects have allowed us to obtain an average time of effect of less than 2 seconds (standard deviation 1 sec), in which it is appropriate to include a manual reaction time of about 0.4 sec.

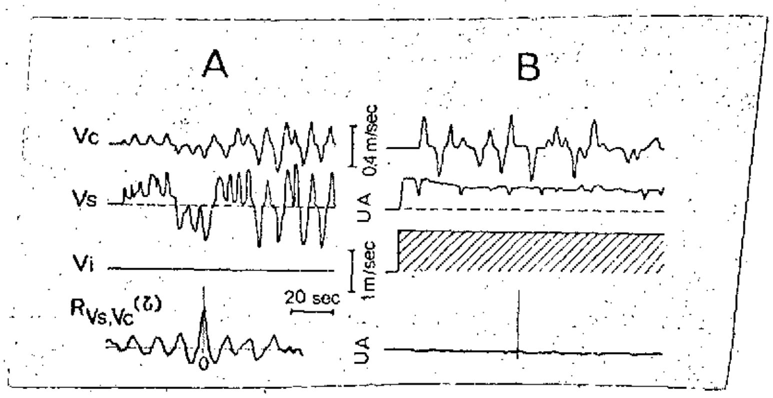

Fig. 3--Interaction between the sensations of speed induced by the visual scene (Vi) and by the translation speed of the cart (Vc).

A. From top to bottom: speed of the cart, subjective speed Vs, and speed of the visual scene Vi, which is zero here. Note that the subject detects successfully the changes in speed of the cart (UA = arbitrary units).

B. From top to bottom: speed of the cart, subjective speed, and speed of the visual scene (which is constant and equal to 1m/sec). Note that the subject always indicates that the movement of the cart is forward, even though it moves backward as well as forward.

Cross-correlation functions Rvs, Vc(τ) between the subjective speed and the speed of the cart in case:

a. The visual scene is fixed; b. the visual scene is moving (Vi - 1 m/sec). Note that in the second case the maximum value of R is more than 200 times smaller.

INTERACTION BETWEEN VISUAL MOVEMENT AND ACCELERATION.--The vestibular receptors are detectors of angular acceleration (the semi-circular canals) and linear acceleration (the utricle and saccule) of the head; during a translation at constant speed, only the component of gravitational acceleration in the plane of the utricular and saccular receptors is detected, thereby providing an evaluation of the inclination of the head relative to the gravitational field. In order to compare the relative contributions of labyrinthine receptors and peripheral vision in the perception of movements themselves, the Vs was measured during displacements of the cart along the axis of symmetry of the system, the visual scene being fixed or animated with a constant apparent speed (Vi - 9 cm/sec), all this being done with nine subjects. In the case where Vi = 0, the subject correctly detects the variations in speed of the cart, as is indicated by the graph in figure 3A, as well as by the cross-correlation function R (Vs, Vc). /1608

When, on the other hand, the images go by at a speed Vi = 1 m/sec (fig. 3B), the 9 subjects incorrectly evaluated the movements of the cart, which they showed as losses relative to the average speed imposed by the sensation of subjective speed of visual origin Vs. This effect is very strong under the conditions of our experiment and demonstrates the existence of a central interaction of visual and non-visual information whose mechanism is still to be elucidated.

DISCUSSION.--The results given here confirm the role of the peripheral retina in elaboration of the sensation of exocentric linear movement whose appearance threshold is very low. In nature, during a translation at constant speed (zero acceleration) the labyrinthine apparatus gives no information regarding the movement of the body, since its specific stimulus is the acceleration of the head. Information of visual origin is therefore essential. When, on the other hand, the speed varies, the two kinds of information, visual and labyrinthine, interact. Our results prove that a constant passing of images can modify the vestibular and proprioceptive evaluations of movement, to the point of causing a false evaluation of the objective direction of the displacement. Furthermore, the presentation of images to the upper part of the visual field evokes an impression of inclination of the trajectory that may be due either to a conflict between visual information (which indicates a displacement) and otolithic information (which has detected no acceleration), or to a combination of a sensation of rotation about a horizontal axis ([5]) (the "circular vection" of Mach) and of translation. Some observations not reported here also indicate that this conflict leads to posture changes as well as to modifications of depth perception which are also indications of a reorganization of the spatial references at a central level.

(*) Session of January 14 1974

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